REMARKS

The undersigned notes the Request for Continued Examination (RCE) Transmittal submitted October 23, 2006, in the above-identified application, requesting a suspension of action for three (3) months. See also the second paragraph of the Remarks in the Submission Under 37 CFR 1.114 (Amendment) filed concurrently with the RCE Transmittal, noting the request for suspension of action. Unfortunately, the Examiner issued the Office Action of January 3, 2007, prior to the end of the suspension period. Applicants are proceeding with examination of the above-identified application based upon the Office Action mailed January 3, 2007, notwithstanding early issuance thereof.

By the present amendments, Applicants are amending each of the previously considered independent claims in the application, that is, claims 62, 65, 69, 89, 93 and 97, to emphasize that the polishing medium has a property that a ratio of a polishing rate of the specified layer or surface "of tantalum, a tantalum alloy or a tantalum compound", using the polishing medium, to a polishing rate of a conductor "of copper, copper alloy or copper oxide", using the polishing medium, is greater than 1.

Moreover, Applicants are adding new claims 113-123 to the application. Claims 114, 116, 118, 120 and 122 recite subject matter expressly set forth in claim 25, but are dependent respectively on claims 65, 69, 89, 93 and 97. Claims 113, 115, 117, 119, 121 and 123, dependent respectively on claims 25, 114, 116, 118, 120 and 122, recite that the abrasive grains are made of a material selected from the group consisting of colloidal silica and colloidal alumina. Note, for example, the paragraph bridging pages 22 and 23 of Applicants' specification.

It is respectfully submitted that all of the claims presented for consideration by the Examiner patentably distinguish over the teachings of the prior art applied by the Examiner in rejecting claims in the Office Action mailed April 24, 2006, that is, the teachings of the U.S. patents to Lee, et al., No. 6,171,352, and to Hardy, et al., No. 6,238,592, under the provisions of 35 USC 102 and 35 USC 103.

It is respectfully submitted that the references as applied by the Examiner would have neither disclosed nor would have suggested such polishing medium as in the present claims, having abrasive grains, with the medium also including, inter alia, an oxidizing agent, a protective-film-forming agent, an acid and water, and wherein (a) the polishing medium has a pH of 3 or less and (b) includes the oxidizing agent in a concentration of from 0.01% by weight to 3% by weight, (c) the polishing medium has a property of polishing a barrier layer of tantalum, a tantalum alloy or a tantalum compound, which is a barrier layer for a conductor of copper, copper alloy or copper oxide, and (d) the polishing medium also has a property that a polishing rate of the barrier layer of the tantalum material to the polishing rate of the conductor of the copper material, in the polishing medium, is greater than 1 (that is, the polishing medium has a selectivity for the polishing of the barrier layer of the tantalum material). See claim 62. Note also claim 89, reciting specific materials in the medium. See also claims 103, 105, 108 and 110. Note also claims 111 and 112, further defining the polishing rate ratio.

In addition, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested such polishing medium as in the present claims, having the recited components with amount of oxidizing agent of 0.01% by weight to 3% by weight and the medium having a pH of 3 or less, the medium having a property of being capable of chemical-mechanical

polishing a surface having at least one of tantalum, a tantalum alloy and a tantalum compound, and also having a property that the polishing rate of this surface of tantalum material, using this polishing medium, to the polishing rate of a conductor selected from the group consisting of copper, copper alloy and copper oxide, using this polishing medium, is greater than 1. See claims 65 and 69. Note also claims 93 and 97, reciting specific materials for components of the polishing medium.

Moreover, it is respectfully submitted that the applied references would have neither disclosed nor would have suggested such polishing medium as in the present claims, as discussed previously in connection with independent claims 62, 65, 69, 89, 93 and 97, including abrasive grains, and wherein the abrasive grains have an average particle diameter of 50 nm or less and the abrasive grains have a standard deviation of particle size distribution in a value of more than 5 nm (see claims 25, 114, 116, 118, 120 ands 122); and, more specifically, wherein the abrasive grains are made of colloidal silica or colloidal alumina (see claims 113, 115, 117, 119, 121 and 123).

Furthermore, it is respectfully submitted that the applied references would have neither taught nor would have suggested such polishing medium as in the present claims, having features as discussed previously in connection with claim 62, and wherein the medium further includes a water-soluble polymer, with the concentration of oxidizing agent in the polishing medium being in a range of from 0.01% by weight to 1.8 % by weight. Note, for example, claim 27.

In addition, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested the polishing medium for chemical-mechanical polishing having components as referred to previously, and having a polishing-rate ratio of tantalum-containing material to

copper-containing material that is greater than 1, and a polishing rate ratio of specified tantalum-containing material to silicon dioxide of more than 10. See claim 51.

Moreover, it is respectfully submitted that the teachings of the applied prior art would have neither disclosed nor would have suggested the other aspects of the present invention as in the remaining, dependent claims being considered on the merits, including (but not limited to) the amount of abrasive grains mixed into the polishing medium, as in, for example, claim 26; and/or wherein the oxidizing agent is included in the polishing medium in a concentration of from 0.01% by weight to 1.5% by weight (note, for example, claim 29; see also claims 68, 72, 92, 96 and 100); and/or wherein the acid of the polishing medium is an organic acid (see, e.g., claim 30), in particular, wherein such acid is at least one selected from the group thereof set forth in claim 31; and/or wherein the medium includes hydrogen peroxide (see claims 101, 102, 104, 106, 1207 and 109).

Moreover, attention is directed to the Declaration under 37 CFR 1.132 of Mr. Y. Kurata, one of the named inventors in the above-identified application, providing evidence of unexpectedly better results achieved according to the present invention, including ranges of amount of oxidizing agent, and pH of the medium, as in the present claims. This Declaration was submitted with the Submission (Amendment) filed June 6, 2005, and an additional copy was submitted with the Request For Clarification filed September 6, 2005. As discussed infra, it is respectfully submitted that this evidence establishes unexpectedly better results achieved by the present invention, so as to clearly support a conclusion of unobviousness of the presently claimed subject matter. Note Manual of Patent Examining Procedure (MPEP) 2131.03, sub-section II.

The presently claimed invention, being considered on the merits herein, is directed to a polishing medium, for chemical-mechanical polishing, having abrasive grains.

In metal formation such as in the formation of damascene wirings of copper or copper alloy or the formation of plug wirings of tungsten, a phenomenon called "thinning", in which the thickness of wiring becomes small together with an interlaminar insulating film, may occur when an interlaminar insulating film of, e.g., silicon dioxide, is polished at a rate close to the rate of polishing the metal film. As a result, there may be caused an increase in wiring resistance or a non-uniformity in resistance ascribable to pattern density. Hence, it is desired that the polishing medium for chemical-mechanical polishing has a property that the polishing rate of a silicon dioxide film is sufficiently smaller than that of the metal film to be polished. Note the last paragraph on page 5 of Applicants' specification.

It is also desired that in performing the metal polishing, "dishing" of the surface of the metal wiring, wherein the surface becomes hollow at the middle thereof like a dish, resulting in a bad effect on flattening, be avoided.

In chemical-mechanical polishing of, e.g., a layer of copper or copper alloy of wiring, together with polishing of, e.g., a layer of tantalum, tantalum alloy, tantalum nitride or other tantalum compound as a barrier layer (tantalum being most commonly used as a barrier metal film), a two-step polishing method has been proposed, having a first step of polishing the copper or copper alloy and a second step of polishing the barrier layer conductor underlying the copper or copper alloy. In this two-step method, and in particular in the second step of polishing the tantalum-containing material, used for the barrier layer, it is important to polish the barrier layer without thinning the silicon dioxide film, and also while avoiding dishing of

copper-containing material of the wiring. Note, in particular, the paragraph bridging pages 6 and 7 of Applicants' specification.

Against this background, and as a result of extensive studies performed by the present inventors, the inventors have discovered that the polishing of the tantalum-containing materials proceeds with ease, without undue polishing of the copper-containing conductor or of the silicon oxide, when the polishing medium, having abrasive grains, has (a) a low pH and (b) includes the oxidizing agent in a low concentration. Thus, according to the present invention, Applicants provide a polishing medium having specified components, including abrasive grains, and also including an oxidizing agent and a protective-film-forming agent, wherein the polishing medium has a pH of 3 or less and the oxidizing agent is included in a concentration of from 0.01-3% by weight, achieving objectives of the present invention of a relatively high polishing rate of the material of the barrier layer, while avoiding dishing and thinning, respectively, of the, e.g., copper wiring and of the oxide insulator, and which additionally can avoid scratches from occurring in the wirings. Thus, as described on pages 8 and 9 of Applicants' original disclosure, the present inventors have discovered that the polishing of the tantalum, tantalum alloy, tantalum nitride and other tantalum compounds which are used as the barrier layer, proceeds with ease in a low pH range and where the oxidizing agent is included in the medium at a low concentration. Moreover, at such low pH and low concentration of the oxidizing agent, etching rate of copper or copper alloy does not increase, avoiding dishing problems.

More specifically, as described in the sole full paragraph on page 16 of Applicants' specification, in general when the polishing medium has a pH of less than 3, etching rate of the copper or copper alloy film is so high as to make it difficult

for the protective-film-forming agent to control the etching. However, in the present invention, the concentration of the oxidizing agent is so sufficiently low that the protection-film-forming agent can control the etching of the copper-containing material, so that removal rate of the copper-containing material is low.

The results of selective polishing of the tantalum-containing material, with respect to the conductor of copper-containing material, is particularly surprising in light of the relative softness of the copper-containing materials to the relatively hard tantalum-containing materials. That is, as can be appreciated, tantalum-containing materials are relatively harder than the copper-containing materials, and it would have been expected that polishing of copper-containing materials would proceed at a higher rate than the polishing of the tantalum-containing material in polishing media. To the contrary, and with use of the polishing medium as in the present claims, including wherein such polishing medium has a pH of 3 or less and a relatively low amount of oxidizing agent (a concentration of from 0.01% by weight to 3% by weight), it has been unexpectedly found that this composition has selectivity for the polishing rate of the tantalum-containing compound as compared to polishing rate for the copper-containing compound, providing advantages achieved by the present invention including, for example, decreased dishing of the copper-containing material conductor.

Such selectivity is particularly surprising in connection with the present invention, utilizing abrasive grains, when taking into consideration hardness of copper-containing materials, as compared with hardness of tantalum-containing materials. That is, as mentioned previously, copper-containing materials are relatively soft, as compared with the softness of tantalum-containing compounds. Notwithstanding this, wherein it would appear that polishing with a polishing medium

containing abrasive grains would polish the copper-containing material at a more rapid rate than polishing of the tantalum-containing material, according to the present invention the selectivity for polishing of the tantalum-containing material relative to the copper-containing material is greater than 1, using, e.g., the medium as in the present claims having both a low pH and relatively low concentration of oxidizing agent, with the abrasive grains. Note, for example, page 16, lines 1-20, of Applicants' specification.

Furthermore, by utilizing abrasive grains having an average particle diameter as in various of the present claims, the polishing rate of silicon dioxide is decreased, further avoiding any "thinning" problems. See the paragraph bridging pages 21 and 22 of Applicants' specification.

As for unexpectedly better results achieved according to the present invention, attention is respectfully directed to the aforementioned Declaration under 37 CFR 1.132, and in particular the Experiments described therein and experimental results set forth therein.

As seen in Additional Experiment 1 on pages 1-4 of the Declaration, Chemical A, within the scope of the present invention, achieved a high removal rate of tantalum nitride and tantalum as compared to the removal rate of copper and silicon oxide, while Chemicals B and C, outside the scope of the present invention, had higher rates of polishing of copper and also had relatively low polishing rates of the tantalum-containing materials. Additional Experiment 2 on pages 5 and 6 of the Declaration shows that with use of a polishing medium according to the present invention, including abrasive grains, the removal rate increased with decrease of abrasive size, which is unexpected (removal rate increasing with increased abrasive size using chemicals outside the scope of the present claims, or in removing silicon

oxide using Chemical A within the scope of the present claims or Chemical B outside the scope of the present invention).

In Additional Experiment 3 on pages 7 and 8 of the Declaration, it can be seen that a high removal rate of tantalum nitride and tantalum, as well as improved selectivity of removing tantalum-containing compounds as compared with copper, is achieved at relatively low pH within the scope of the present claims. Additional Experiment 4 on pages 9 and 10 of the Declaration shows that at relatively low oxidizing agent concentration (a concentration of less than 3% by weight), polishing rate of tantalum and tantalum nitride are relatively high, as compared with concentrations over 3% by weight; and selectivity for removal of tantalum-containing compounds as compared with polishing of copper can be achieved at relatively low oxidizing agent concentration.

Additional Experiment 5 on pages 11 and 12 of the Declaration shows that with polishing media containing a water-soluble polymer (polyacrylic acid ammonium salt), decreased oxidizing agent concentration achieves increased removal of tantalum-containing materials, contrary to expectation; and, moreover, at low oxidizing agent concentration, a selectivity for removal of tantalum-containing material relative to removal of copper can be achieved. Additional Experiment 6 on pages 13 and 14 of the Declaration shows that decrease of pH can achieve a high polishing speed for tantalum and tantalum nitride materials, which is the opposite result achieved in connection with copper and titanium nitride films. That is, as seen in Additional Experiment 6, polishing speeds of the copper film and the titanium nitride film show behaviors completely different from that of the tantalum-containing film.

It is respectfully submitted that these Additional Experiments 1-6 show unexpectedly better results with respect to polishing of tantalum-containing materials, for polishing media, containing abrasive grains, as in the present claims having a relatively low pH and a relatively small amount of oxidizing agent, supporting unobviousness of the presently claimed invention.

In Item 6 on pages 5 and 6 of the Office Action mailed January 3, 2007, the Examiner contends that the Declaration under 37 CFR 1.132 is not persuasive, because it does not compare the claimed subject matter with the closest prior art, and that it refers only to the "system" described in the present application and not to individual claims of the application. It is respectfully submitted, however, that the Declaration provides comparative evidence with respect to media closer to the present invention than the closest prior art, and thus constitutes a proper test for establishing unobviousness. See, e.g., MPEP 716.02(e). While the Examiner contends that the Declaration refers only to the "system", it is respectfully submitted that the test data in the Declaration provides evidence with respect to the subject matter of the claims of the above-identified application, establishing unexpectedly better results in connection therewith.

The contention by the Examiner in the paragraph bridging pages 5 and 6 of the Office Action mailed January 3, 2007, that "some of the independent claims [recite] the composition having no abrasive grains", is respectfully traversed. It is respectfully submitted that all of the claims presently being considered on the merits in the above-identified application recite that the polishing medium has abrasive grains.

Lee, et al. discloses a chemical-mechanical abrasive composition for semiconductor processing, which includes 70-95% by weight of an aqueous

medium, 1-25% by weight of an abrasive and 0.1-20% by weight of an abrasion accelerator, the abrasion accelerator including a monocarboxy group- or an amido group-containing compound and optionally a nitrate salt. See column 2, lines 38-48. This patent goes on to disclose that the abrasive composition can further include 1-15% by weight of, and preferably 4-8% by weight of, an oxidant. See column 2, lines 63-65. Note also column 3, lines 3-7 for specific oxidants. This patent further discloses that when used in a copper production process, the abrasive composition may include benzotriazole and/or its derivatives to inhibit rapid copper corrosion. See column 4, lines 13-20. Note also column 4, lines 30-40, for a disclosure of adjustment of the pH, with respect to polishing various materials. These various materials include copper and tungsten, but do not include tantalum, tantalum alloys or tantalum compounds. Note also specific compositions in the Examples.

In column 6, lines 56-62, Lee, et al. discloses that in the process for producing integrated circuits, Ta is most commonly used as a barrier metal film; and that, nevertheless, since Ta has a high chemical resistance, achieving effective polishing of Ta is usually difficult. This patent goes on to describe that it has been found that the abrasive composition disclosed therein is able to provide excellent polishing efficacy for Ta, as illustrated in, for example, Examples 4-8 in Lee, et al. Examples 4-8 refer to preparation steps of Example 1 in Lee, et al.; Example 1 of Lee, et al. describes adjustment of the slurry to have a pH of about 3.8. See column 4, lines 62 and 63 of Lee, et al.

It is respectfully submitted that Lee, et al. would have neither taught nor would have suggested the combination of relatively low pH and relatively low amount of oxidizing agent, and advantages thereof, e.g., in polishing tantalum-containing

material with selectivity relative to polishing copper-containing materials and/or silicon oxide.

Note that the Examples in Lee, et al. disclose adjustment of the pH of the slurry to have a pH of about 3.8 in Example 1, and to have a pH of about 2.2 (in Example 3). Comparative Example 1 of Lee, et al. also discloses adjustment of the pH to have a pH of about 2.2. Moreover, Lee, et al. discloses that polishing tantalum is difficult. See, for example, column 6, lines 56-61 of Lee, et al. But note, also, Table 3 in column 8 of Lee, et al. Taking the teachings of Lee, et al. as a whole, it is respectfully submitted that such teachings do not disclose, nor would have suggested, the present invention, using a relatively low concentration of oxidizing agent and relatively low pH in the polishing medium containing abrasive grains, and advantages achieved thereby.

Moreover, note that Table 3 of Lee, et al., which shows tantalum removal rate, shows such removal rate in connection with Examples 4-8 and Comparative Example 2. However, note that Examples 4-8 refer to the same preparation steps as in Example 1, in which the slurry was adjusted to have a pH of about 3.8. It is respectfully submitted that Lee, et al., either alone or in combination with the teachings of the other applied reference, would have neither disclosed nor would have suggested such pH as in the present claims for polishing of tantalum, much less the combination of pH and oxidizing agent concentration as in the present claims and advantages thereof for selective polishing of tantalum-containing material as compared to polishing of copper-containing material.

It is emphasized that in all examples of Lee, et al., describing polishing of Ta, the pH is higher than that in the present claims. It is respectfully submitted that Lee, et al. would have taught away from the present invention, including the relatively low

pH and relatively low concentration of oxidizing agent, achieving selective polishing of the Ta-containing material as compared with the Cu-containing material.

The contention by the Examiner in the sentence bridging the last three lines on page 2, and first three lines on page 3, of the Office Action mailed January 3, 2007, with respect to relative polishing rates, is respectfully traversed. It is respectfully submitted that Lee, et al. discloses polishing media including various different components, such as, e.g., an abrasion accelerator; and, moreover, discloses use of a relatively high pH for polishing of Ta. It is respectfully submitted that Lee, et al. would have taught away from the presently claimed subject matter, including selectivity, even where various of the components may be common.

It is respectfully submitted that the teachings of the secondary reference as applied by the Examiner, Hardy, et al., would have not have rectified the deficiencies of Lee, et al. such that the presently claimed invention as a whole would have been obvious to one of ordinary skill in the art.

Hardy, et al. discloses a family of working liquids useful in modifying exposed intermediate surfaces of structured wafers for semiconductor fabrication, the working liquid being a solution of initial components comprising an oxidizing agent; an ionic buffer; a passivating agent; a chelating agent selected from iminodiacetic acid and salts thereof; and water. This patent discloses that the passivating agent may be an azole derivative preferably selected from benzotriazole, tolyltriazole or combinations thereof. See column 3, lines 40-45. See also column 7, lines 19-30; and column 7, line 64 to column 8, line 2. Note also column 9, lines 30-33; and column 9, line 67 to column 10, line 3, disclosing that the average particle size of inorganic particulates, included in the working liquid to increase removal rate of the metal and/or dielectric,

to be less than about 1000 Angstroms. See also, column 10, line 9, disclosing amount of the inorganic particulates in the working liquid.

Even assuming, arguendo, that the teachings of Hardy, et al., were properly combinable with the teachings of Lee, et al., it is respectfully submitted that these combined teachings would have neither disclosed nor would have suggested such polishing medium as in the present claims, having pH and concentration of oxidizing agent, and also having average particle diameter and standard deviation of particle size distribution of the abrasive as in various of the present claims, which achieves advantages according to the present invention as discussed previously, and, as shown, e.g., in Additional Experiment 2 in the aforementioned Declaration submitted in the above-identified application.

The Examiner has stated, without any reasoning or evidence in support thereof, that it would have been obvious for one skilled in the art "to determine the standard deviation of the particle size distribution through test runs in order to provide a slurry for the polishing with a reasonable expectation of success". Clearly such conclusion concerning determination of standard deviation of particle size distribution, without any reasoning or evidence in support thereof, is improper. See In re McKellin, 188 USPQ 428 (CCPA 1976). Particularly in view of advantages achieved by the present invention due to average particle diameter and standard deviation of particle size distribution as in the present claims, discussed previously, it is respectfully submitted that the conclusion by the Examiner without reasoning or evidence in support thereof is improper.

The conclusion by the Examiner in Item 5 on page 5 of the Office Action mailed January 3, 2007, that Lee, et al. would inherently have polishing rate ratios as in the present claims, is respectfully traversed. As indicated previously, noting all

components in the composition of Lee, et al., and noting also the disclosure in Lee, et al. that effective polishing of Ta is usually difficult, with examples therein of polishing Ta having relatively high pH, it is respectfully submitted that the Examiner has not established inherency of polishing rates, in abrasive compositions of Lee, et al.

The contention by the Examiner in the second paragraph of Item 5, that there is not a specific teaching against using a lower pH in Lee, et al., is respectfully traversed, with respect to polishing media therein for Ta. Again, it is emphasized that Lee, et al. discloses difficulty in effectively polishing Ta, with polishing efficacy thereof at relatively high pH. It is respectfully submitted that such disclosure in Lee, et al. would have taught away from the composition as in the present claims, having properties therein and with a relatively low pH in combination with a relatively low concentration of oxidizing agent.

In view of the foregoing comments and amendments, reconsideration and allowance of all claims presently in the application are respectfully requested.

To the extent necessary, Applicants petition for an extension of time under 37 CFR 1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to the Deposit Account of Antonelli, Terry, Stout & Kraus, LLP, Deposit Account No. 01-2135 (case No. 1204.41191X00) and please credit any excess fees to such Deposit Account.

Respectfully submitted,

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